

A System And Method For Testing Fluid Flow Of A Centerline Fuel Tank Of An Aircraft

FIELD OF INVENTION

5 The invention relates broadly to a system and method for testing fluid flow of a centerline fuel tank of an aircraft. In particular, the invention relates to a system and method for testing fluid flow of a centerline fuel tank of a fighter aircraft.

BACKGROUND

A fighter aircraft can have a centerline drop tank (CDT) mounted externally to the aircraft fuselage.
10 The main purpose of the CDT is to carry additional fuel to support long flight missions. Besides this, the CDT may also be modified and used for smoke generation during an aerobatic display.

Fighter aircraft are capable of doing maneuvers, such as rolling, diving, banking, upright and inverted flight maneuvers. During an aerobatic display, fighter aircraft perform a combination
15 of these maneuvers with smoke generation to give outstanding visual effects to an audience watching the aerobatic display.

When a fighter aircraft performs one or more of the above flight maneuvers, the fuel inside the CDT is subject to complex movements. Presently available test equipment on the ground is not capable of
20 simulating the fluid movements from the CDT during different flight maneuvers. Furthermore, presently available test equipment is not capable of simulating the fluid movements from the CDT during different flight maneuvers when the CDT is internally modified e.g. to include a smoke generation system.

25 There is thus a need to provide system and method for testing fluid flow of a centerline drop tank of an aircraft and, more particularly, a fighter aircraft that seeks to address one or more of the above disadvantages.

SUMMARY

30 According to a first aspect of the present invention, there is provided a system for testing fluid flow of a fuel tank of an aircraft, the system comprising: a fuel tank for receiving a predefined volume of a fluid, the fuel tank having an outlet for outputting the fluid; a pressure generator to generate a predefined internal pressure inside the fuel tank; a first structure onto which the fuel tank is mounted, the first structure being operable to rotate the fuel tank about a first axis; a

second structure onto which the first structure is mounted, the second structure being operable to rotate the fuel tank about a second axis, and a flow meter connected to the outlet of the fuel tank for measuring a flow rate of the fluid in different positions of the fuel tank.

- 5 The system may further comprise: a sump installed inside the fuel tank, wherein when the fuel tank is in a normal position: the sump is operable to accumulate a reserve volume of fuel, and the flow rate measured by the flow meter corresponds to the flow rate of the fuel from the fuel tank as a result of the pressure generated by the pressure generator; and when the fuel tank is in an inverted position: the flow rate measured by the flow meter corresponds to the flow rate of
10 the accumulated fuel from the sump as a result of bleed air pressurization.

The fuel tank may be co-axially mounted to the first structure. The first structure may be mounted to the second structure.

- 15 The flow meter may be mounted on the outer casing of the fuel tank.

The second axis may be orthogonal to the first axis. The second axis may be located at a point of intersection of the first structure and the second structure.

- 20 The rotation of the first structure about the first axis may be provided by a first motor mounted on one side of the second structure. The rotation of the second structure about the second axis may be provided by a second motor mounted on one side of the first structure.

- The first and second motors may be controlled by an operator, wherein a combination of
25 movements of the first and second motors are made to simulate one or more aircraft maneuvers comprising a vertical climb, a diving, a rolling, a banking, a normal and an inverted position.

A first fluid pipe may connect the outlet to the flow meter and the first fluid pipe may be mounted to the body of the fuel tank.

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According to a second aspect of the present invention, there is provided a method for testing fluid flow of a fuel tank of an aircraft, the method comprising the steps of: receiving a predefined volume of a fluid in the fuel tank, the fuel tank having an outlet for outputting the fluid; connecting a pressure generator to the fuel tank; mounting a second structure onto the first

structure; operating the pressure generator to generate a predefined internal pressure inside the fuel tank; rotating the first structure about a first axis; rotating the second structure about a second axis; connecting the outlet of the fuel tank to a flow meter; and measuring a flow rate of the fluid in different positions of the fuel tank.

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The method may further comprise the steps of: providing a sump inside the fuel tank, accumulating a reserve volume of fuel in the sump and measuring the flow rate of the fuel from the fuel tank as a result of the pressure generated by the pressure generator, when the fuel tank is in a normal position; and measuring the flow rate of the accumulated fuel from the sump as a result of bleed air pressurization, when the fuel tank is in an inverted position.

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BRIEF DESCRIPTION OF THE DRAWINGS

Embodiments of the invention will be better-understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

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Figure 1 is a side view of a system for testing fluid flow of a centerline fuel tank of an aircraft in accordance with an embodiment of the present invention;

Figure 2 is another side view of Figure 1;

Figure 3 is a perspective view of Figure 1;

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Figure 4 is flow chart to illustrate a method for testing fluid flow of a centerline fuel tank of an aircraft in accordance with an embodiment of the present invention;

Figure 5 is a perspective view of an internal portion of a centreline drop tank of an aircraft with a smoke generation system;

Figure 6 is a schematic diagram of the centreline drop tank of Figure 5;

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Figure 7 is a perspective view of a sump utilised in the centreline drop tank of Figure 5;

Figure 8 is a cut-away perspective view of the sump of Figure 7; and

Figure 9 is another cut-away perspective view of the sump of Figure 7.

DETAILED DESCRIPTION

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Embodiments of the present invention provide a transient environment (roll & pitch), close to actual aircraft maneuvers, to determine the feasibility of a mechanical system design in an aircraft.

Embodiments of the present invention provide a two-axis jig for ground testing the fluid flow rate in a CDT of an aircraft while performing various flight maneuvers.

Embodiments of the present invention provide a two-axis jig for determining, on the ground, the fluid flow rate as well as the continuity of fluid flow in a CDT of an aircraft, while performing various flight maneuvers.

- 5 Embodiments of the present invention provide a two-axis jig for ground testing the feasibility of a conceptual design of a smoke generation system in a CDT of an aircraft while performing various flight maneuvers.

- 10 Embodiments of the present invention provide a two-axis jig for performing tests associated with a conceptual design of any fluid system to be installed on an aircraft, where flow and continuity is to be determined under various simulated flight maneuvers.

- 15 Figure 1 is a side view of a system 100 for testing fluid flow of a centerline drop tank (CDT) 103 of an aircraft in accordance with an embodiment of the present invention. The system consists of a two-axis jig 150 in which a CDT 103 is operable to move about two orthogonal axes i.e. within a horizontal support structure 105 and vertical support structure 101.

- 20 The CDT 103 is co-axially mounted onto the centre of a horizontal support structure 105. The horizontal support structure 105 can be a solid rectangular frame. A first motor 115 mounted on one side of the vertical support structure 101 is operable to move the horizontal support structure 105 in clockwise and anti-clockwise directions, about a first axis i.e. in a direction 121, the first axis being located at a point of intersection of the vertical support structure 101 and the horizontal support structure 105. The horizontal support structure 105 and vertical support structure 101 can be made of a material, such as mild steel. It is understood that other materials may be used.

- 25 The CDT 103 may receive a fluid (e.g. water) through a bleed air inlet 620 (refer to Figure 6). Alternately, a separate opening (not shown) may be conveniently provided on the CDT 103 for filling the CDT 103 with the fluid. A first fluid pipe 107 connects an output from the CDT 103 to a flow meter 109 for visually monitoring the fluid flow rate of the system 100. The output from the flow meter 109
30 terminates with a second fluid pipe 111. The second fluid pipe can be a flexible hose. The distal end of the second fluid pipe 111 has an opening for exhausting the fluid. The two output fluid pipes 107 and 111, and the flow meter 109, are attached to the outer casing of the CDT 103. A shut-off valve (not shown) is installed adjacent to the flow meter for enabling the operator to manually open or close the fluid flow of the system 100.

Figure 2 is another side view of Figure 1, in a direction perpendicular to Figure 1. A second motor 203 mounted on one side of the horizontal support structure 105 is operable to move the CDT 103 in clockwise and anti-clockwise directions, about a second axis i.e. in a direction 205, the second axis being orthogonal to the first axis and located at a point of intersection of the vertical support structure 101 and the horizontal support structure 105.

The movements of the first motor 115 and the second motor 203 can be controlled by an operator operating the system 100. The operator can simulate different flight maneuvers by controlling the two motors 115, 203. For example, vertical climbing or diving maneuvers can be simulated by turning the motor 115 in anti-clockwise or clockwise directions. Similarly, rolling, banking and inverted flight maneuvers can be simulated by controlling the direction and angle of rotation of the motors 115, 203.

The motors 115, 203 may be controlled by a standard off-the-shelf digital inverter providing clockwise (CW) / counter clockwise (CCW) control pulses.

In order to perform the tests, firstly, the CDT 103 is filled with an adequate amount of fluid e.g. water (instead of fuel). Then, the CDT 103 is pressurized using e.g. a pressure generator (not shown) to generate a predefined pressure. A pressure gauge (not shown) may be attached to the pressure generator for measuring the pressure. The pressure measured at pressure corresponds to the bleed air pressure at the bleed air inlet 620. An operator activates the system 100 once pressurization is completed. The operator can then simulate different aircraft maneuvers by controlling the two motors 115, 203. The pressurized water from the CDT 103 is expelled out through the first fluid pipe 107. For each of the maneuvers, the operator can visually see the flow rate and the flow continuity from the readings on the meter 109 as well as from the quantity of water flowing out through the second fluid pipe 111.

Figure 3 is a perspective view of Figure 1, shown without the fluid pipes 107, 111 and the flow meter 109. As indicated, the system 100 can be mounted on a pedestal 301.

Figure 4 is a flow chart to illustrate a method, designated generally as reference numeral 400, for testing fluid flow of a centerline fuel tank of an aircraft in accordance with an embodiment of the present invention. The method comprises the steps of: receiving a predefined volume of a fluid in the fuel tank, as shown by the reference numeral 401, the fuel tank having an outlet for outputting the fluid; connecting a pressure generator to the fuel tank, as shown by the reference

numeral 403; mounting the fuel tank onto a first structure, as shown by the reference numeral 405; mounting a second structure onto the first structure, as shown by the reference numeral 407; operating the pressure generator to generate a predefined internal pressure inside the fuel tank, as shown by the reference numeral 409; rotating the first structure about a first axis, as shown by the reference numeral 411; rotating the second structure about a second axis, as shown by the reference numeral 413; connecting the outlet of the fuel tank to a flow meter, as shown by the reference numeral 415; and measuring a flow rate of the fluid in different positions of the fuel tank 417.

The system 100 can also be used for testing fluid flow rates associated with a smoke generation system incorporated inside the CDT 103 of an aircraft, while performing various flight maneuvers. The following sections describe a smoke generation system and method for an aircraft that can be incorporated into the CDT 103 described above.

Figure 5 is a perspective view of an internal portion of a centerline drop tank 500 with a smoke generation system in accordance with an embodiment of the present invention.

The centerline drop tank (CDT) 500 is shown without its outer casing 602 (refer to Figure 6). Mounted to the inner circumference of the outer casing 602 are four solid ring-like supports 503, 505, 507, 509. The outer and the inner circumference of the four solid ring-like supports 503, 505, 507, 509 are elliptical in shape. The CDT 500 is mounted below the fuselage of an aircraft such that the edge closer to the ring-like support 503 faces the nose of the aircraft, while the edge closer to the ring-like support 509 faces the tail of the aircraft.

The ring-like supports 503, 509 are mounted at the two edges of the mid section of the centerline drop tank 500, while the ring-like supports 505, 507 are axially mounted in between the tank supports 503, 509. A cylindrical support 527 is centrally mounted to the longer diameter of the ring-like supports 505, 507.

An elongate and hollow sump 501 having a rectangular cross section is mounted to the inner edges of the ring-like supports 503, 509 by a pair of brackets 511, at the bottom of the CDT 500. The sump 501 is operable to trap a volume of fuel from the CDT 500 for use during inverted flight maneuvers. The height of the sump 501 is substantially smaller than its length such that the upper surface of the sump 501 is substantially below the cylindrical supports 527. It is

understood that the size and shape of the sump 501 can be altered according to the size and shape of the CDT 500.

The sump 501 has an opening 603 (refer to Figure 6) on its bottom surface 730 (refer to Figure 7). A flapper valve 513 is mounted to a top surface 740 (refer to Figure 7) of the sump 501, in between the ring-like supports 503 and 505. The flapper valve 513 and opening 603 allow fuel entry into the sump 501 when the CDT 500 is in a normal position. Thus, a volume of fuel from the CDT 500 is accumulated in the sump 501 and the sump 501 is in fluid communication with the CDT 500. The volume of fuel accumulated in the sump is sufficient to supply the fuel for smoke generation when the CDT and the aircraft are in an inverted position. The dimensions of the sump 501 can be tailored depending on the capacity and dimensions of the CDT 500.

An elongate and hollow sub-tank 523 can be orthogonally mounted on the sump 501, towards the rear end of the sump 501 and near the ring-like support 509. The width of the sub-tank 523 can be substantially smaller than its length and the length of the sub-tank 523 is equal to the width of the sump 501. The front surface of the sub-tank 523 faces the front end of the CDT 500, while the rear surface is flush with the rear surface of the sump 501. The top surface of the sub-tank 523 has a flapper valve 515, while the bottom surface 605 (refer to Figure 7) of the sub-tank 523 has slots 709 (refer to Figure 7), whereby the sump 501 is in fluid communication with the sub-tank 523. The flapper valve 515 is operable to enable fuel entry when the CDT 500 is in the normal position.

An interconnect 525 connects sub-tank 523 and the fuel pump 517. A top surface 535 of the interconnect 525 is mounted to the outer casing 602 (refer to Figure 6) of the CDT 500. A bottom surface 545 of the interconnect 525 has a flapper valve 607 (refer to Figure 6). The flapper valve 607 closes when the CDT 500 is in the normal position.

A fuel pump 517 is mounted on a bracket 531, which is attached to the ring-like support 509 and the bracket 511. The fuel pump 517 receives power through a tube 529 attached to the inner cylindrical supports 527. An inlet 620 supplies bleed air into the CDT 500. The fuel pump 517 is operable to increase the fluid pressure inside the CDT 500. The increased pressure inside the CDT 500 helps to increase the fuel flow rate, which, in turn, increases the smoke quality.

Figure 6 is a schematic diagram of the CDT 500 of Figure 5 in accordance with an embodiment of the present invention. With reference to Figures 5 and 6, a first fluid pipe 519 connects the pump 517 and the interconnect 525. A second fluid pipe 518 connects the sub-tank 523 and the interconnect 525. For example, the first fluid pipe 519 and the second fluid pipe 518 that are connected to the interconnect 525 may be tubing fittings. A third fluid pipe 521 connects the interconnect 525 to a shut-off valve 609. The compressed fuel from the CDT 500 is discharged through an engine exhaust (not shown) located at the distal end of an output pipe 611 at the distal end of the third fluid pipe 521. A pilot of the aircraft can control the opening and closing of the shut-off valve 609.

During normal operation (i.e. when the aircraft is flying in the normal position and the CDT 500 is in the normal position), the pressure created by the fuel pump 517 and the bleed air pressure inside the CDT 200 drives the fuel inside the CDT 500 to the output pipe 611 via the interconnect 525. During an inverted flight maneuver (when the i.e. when the aircraft and the CDT 500 is turned up side down), the fuel trapped inside the sump 501 is discharged by bleed air pressurization within the CDT 500. The engine exhaust (not shown) located at the distal end of an output pipe 611 then vaporizes the discharged fuel resulting in smoke generation.

During non-inverted maneuvers, the fuel pump 517 creates a high pressure within the interconnect 525 resulting in the closure of the flapper valve 607. This allows continuous fuel flow even when the fuel level in the CDT 500 is below the opening 603 of the sump 501.

During inverted flight maneuvers, the flapper valves 513 and 515 are closed, thus trapping a predetermined volume of fuel within the sump 501. At this position, the fuel pump 517 runs dry (i.e. it does not create any pressure within the first fluid pipe 519) and bleed air pressurization inside the CDT 1 pushes the trapped diesel within the sump 501, through the flapper valve 607 to the interconnect 525, which results in smoke generation.

Figure 7 is a perspective view of a sump 501 utilised in the centreline drop tank 500 of an aircraft in accordance with an embodiment of the present invention.

The sump 501 is an elongate and hollow structure. In this embodiment, the height of the sump 501 is substantially smaller than its length. The sump 501 has a rectangular cross section. The

sump 501 is operable to trap a volume of fuel for use during inverted flight maneuvers. The size and shape of the sump 501 can be altered according to the size and shape of the CDT 500.

5 The sump 501 has a flat top surface 740 and a bottom surface 730. The bottom surface 730 has an opening 603 to receive fuel from the CDT 500. A flapper valve 513 is mounted to the top surface 740 of the sump 501.

10 In order to ensure continuity in the fluid flow when an aircraft is in transition from inverted flight to normal flight, the sump 501 has a plurality of partitions. In an embodiment, the sump 501 has a first partition wall 701 that is parallel to the front surface 450 of the sump 501 and a second partition wall 703 that is perpendicular to the front surface 750 of the sump 501. The first partition wall 701 has two rectangular slots 705 for restricting fluid flow within various chambers of the sump 201. The number and size of partitions as well as the slots inside the sump 501 can be altered according to the capacity of the CDT 500.

15 An elongate and hollow sub-tank 523 is orthogonally mounted on the sump 501, towards the rear surface 710. In this embodiment, the width of the sub-tank 523 is substantially smaller than its length and the length of the sub-tank 523 is equal to the width of the sump 501. The front surface of the sub-tank 523 is parallel to the front surface 750 of the sump 501, while the rear surface of the sub-tank 523 is flush with the rear surface 710 of the sump 501. A flapper valve 515 is mounted to the top surface 760 of the sub-tank 523, while the bottom surface 605 of the sub-tank 523 has a plurality of rectangular slots 709 for restricting fluid flow to/from the sub-tank 523.

20 In order to ensure continuity in the fluid flow when an aircraft is in transition from inverted flight to normal flight, the sub-tank 523 also has two partitions 711 that are parallel to each other. Each of the partitions is perpendicular to a rear surface 720 of the sub-tank 523. A flapper valve 717 is mounted to each of the partitions 711 (refer to Figure 8) for restricting fluid flow within the sub-tank 523.

30 The sump 501 and the sub-tank 523 may be made of a material, such as aluminium. It is understood that other material may also be used.

Figure 8 is a cut-away perspective view of the sump 501 of Figure 7, in which part of the sump 501 and the sub-tank 523 are exposed. The sump 501 has a pair of sidewalls 801 on either end. The first partition wall 701 is located approximately halfway between the two sidewalls 801. The first partition wall 701 has a pair of slots 705 to restrict fluid flow within the sump 501. The second partition wall 703 is perpendicular to the first partition wall 701. The sidewalls 801 and the first partition wall 701 are parallel to each other and are held between the top surface 740 and the bottom surface 730 of the sump by a plurality of brackets 811, 815 and frames 817.

The sub-tank also has a pair of partition walls 711 that are parallel to the sidewalls 819, 821. Each partition wall 711 has a flapper valve 717 for trapping fuel inside the sub-tank 523.

Figure 9 is another cut-away perspective view of a portion of the sump of Figure 7 in which the top surface 740 and the bottom surface 730 of the sump 501 are removed to show the positioning of the partitions 701 and 703.

It will be appreciated by a person skilled in the art that numerous variations and/or modifications may be made to the present invention as shown in the specific embodiments without departing from the spirit or scope of the invention as broadly described. The present embodiments are, therefore, to be considered in all respects to be illustrative and not restrictive.

CLAIMS

1. A system for testing fluid flow of a fuel tank of an aircraft, the system comprising:
 - a fuel tank for receiving a predefined volume of a fluid, the fuel tank having an outlet for outputting the fluid;
 - 5 a pressure generator to generate a predefined internal pressure inside the fuel tank;
 - a first structure onto which the fuel tank is mounted, the first structure being operable to rotate the fuel tank about a first axis;
 - a second structure onto which the first structure is mounted, the second structure being operable to rotate the fuel tank about a second axis; and
 - 10 a flow meter connected to the outlet of the fuel tank for measuring a flow rate of the fluid in different positions of the fuel tank.
2. The system of claim 1, further comprising:
 - a sump installed inside the fuel tank, wherein
 - 15 when the fuel tank is in a normal position:
 - the sump is operable to accumulate a reserve volume of fuel, and the flow rate measured by the flow meter corresponds to the flow rate of the fuel from the fuel tank as a result of the pressure generated by the pressure generator; and
 - when the fuel tank is in an inverted position:
 - 20 the flow rate measured by the flow meter corresponds to the flow rate of the accumulated fuel from the sump as a result of bleed air pressurization.
3. The system of claim 1 or 2, wherein the fuel tank is co-axially mounted to the first structure.
- 25 4. The system of claim 1 or 2, wherein the first structure is mounted to the second structure.
5. The system of any one of the preceding claims, wherein the flow meter is mounted on
- 30 the outer casing of the fuel tank.
6. The system of any one of the preceding claims, wherein the second axis is orthogonal to the first axis.

7. The system of any one of the preceding claims, wherein the second axis is located at a point of intersection of the first structure and the second structure.

8. The system of any one of the preceding claims, wherein the rotation of the first structure about the first axis is provided by a first motor mounted on one side of the second structure.

9. The system of any one of the preceding claims, wherein the rotation of the second structure about the second axis is provided by a second motor mounted on one side of the first structure.

10. The system of claim 8 or 9, wherein the first and second motors are controlled by an operator, and

wherein a combination of movements of the first and second motors are made to simulate one or more aircraft maneuvers comprising a vertical climb, a diving, a rolling, a banking, a normal and an inverted position.

11. The system of any one of the preceding claims, wherein a first fluid pipe connects the outlet to the flow meter, the first fluid pipe mounted to the body of the fuel tank.

12. A method for testing fluid flow of a fuel tank of an aircraft, the method comprising the steps of:

receiving a predefined volume of a fluid in the fuel tank, the fuel tank having an outlet for outputting the fluid;

connecting a pressure generator to the fuel tank;

mounting the fuel tank onto a first structure;

mounting a second structure onto the first structure;

operating the pressure generator to generate a predefined internal pressure inside the fuel tank;

rotating the first structure about a first axis;

rotating the second structure about a second axis;

connecting the outlet of the fuel tank to a flow meter; and

measuring a flow rate of the fluid in different positions of the fuel tank.

13. The method of claim 12, further comprising the steps of:

providing a sump inside the fuel tank,

accumulating a reserve volume of fuel in the sump and measuring the flow rate of the fuel from the fuel tank as a result of the pressure generated by the pressure generator, when the fuel tank is in a normal position; and

measuring the flow rate of the accumulated fuel from the sump as a result of bleed air pressurization, when the fuel tank is in an inverted position.

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